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Original Research Article

A study on chronic obstructive pulmonary disease and its determinants among underground coal mine workers in Bankola area, Durgapur, West Bengal

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ABSTRACT

Background: Chronic obstructive pulmonary disease is a leading cause of morbidity and mortality worldwide that effectuate an economic and social burden that is both considerable and progressive. Mortality from respiratory disease remains an important occupational hazard among coal miners. Inhalation of coal mine dust is known to cause several respiratory diseases including COPD. The current study aimed to estimate the prevalence of COPD among coal miners and to find out the predictors of the same in Bankola Area, Durgapur, West Bengal.
Methods: A cross-sectional study was conducted among 315 coal miners selected by simple random sampling from the list of mines in Bankola Area, Durgapur, West Bengal. The required data was collected by face-to-face interview with the help of a predesigned pretested questionnaire and subsequently clinical examination along with spirometry in an eligible subset of population. Data thus collected had been analysed by SPSS 16.0 version.
Results: Prevalence of COPD among mines was found to be 11.7%. Most of the miners showed obstructive pattern, had Grade 2 severity of airflow limitation (43.2%) whereas 8.2% had Grade 4 severity. Multivariate analysis revealed that miners who were smoking for more than 20 years, working in highly dusty areas and those who were working at coal face had higher odds of developing COPD.
Conclusions: Addressing substance use as well as improvement in working environment including use of personal protective equipment can holistically lead to better respiratory health of the miners.

Keywords: Colliery, Eastern India, Predictors, Respiratory morbidity, Survey

INTRODUCTION

Coal remains the second largest energy source worldwide despite controversies over greenhouse gases and competition from other energy sources. Coal contributes about one-fourth of the world's energy supply and more than one-third of the fuel used to generate electricity. In 2018, 7813.3 million tons (Mt) of coal was produced worldwide, India produced 771 million tons (Mt) primarily mined by two methods: surface or 'opencast' mining, and underground mining.[1] In 2016, India overtook the United States to become the world's second-largest producer of thermal coal and it is the world's second-largest coal consumer, behind China, with coal consumption reaching 942 million tons in 2017.[2] Coal India Limited (CIL) contributes the majority of the coal production in the country through 7 of its wholly owned subsidiaries; which are Eastern Coalfields Limited (ECL), Bharat Coking Coal Limited (BCCL), Central Coalfields Limited (CCL), Western Coalfields Limited (WCL), South Eastern Coalfields Limited (SECL), Northern Coalfield Limited (NCL), and Mahanadi Coalfields

Limited (MCL). West Bengal has the fourth highest coal reserves in India, ECL operates 77 underground mines in the eastern region with approximately 85000 manpower.[3,4]

Coal Mine dust is a heterogeneous mixture of more than 50 different elements and their oxides. Respirable dust in underground mines has been estimated to be 40%-95% coal; the remaining consists of variable mixed dust that is generated from fractured rock on the roof or floor of the mines.[5] Coal mine dust causes a spectrum of lung diseases collectively termed Coal Mine Dust Lung disease (CMDLD). these include coal workers' pneumoconiosis, silicosis, mixed dust pneumoconiosis, dust-related diffuse fibrosis and chronic obstructive pulmonary disease.[6] Estimates of the global burden of chronic non-malignant lung disease demonstrate the significant contribution of occupational exposures, which account for about 13% of all cases of chronic obstructive pulmonary disease (COPD) and about 11% of asthma cases. Altogether, the annual worldwide burden of work-related COPD is about 318,000 deaths per year and about 3.7 million DALY.[7]

Chronic obstructive pulmonary disease is a leading cause of morbidity and mortality worldwide that effectuate an economic and social burden that is both considerable and progressive. COPD prevalence, mortality, and morbidity differ from country to country across the globe. COPD is the result of a complex interplay between long-term cumulative exposure to toxic gases and particles, and amalgamate with a variety of host factors (genetics, airway hypersensitivity, etc.) The prevalence of COPD has been majorly accredited to the prevalence of tobacco smoking, although many studies revealed occupational exposures, outdoor and indoor air pollution as other COPD risk factors. The prevalence and burden of COPD are projected to increase over the coming decades due to sustained exposure to COPD risk factors (growing industrialization, increasing level of pollution) and ageing of the world's population; as longevity increases, more people will express the long-term effects of exposure to COPD risk factors.[8] Mortality from respiratory disease remains an important occupational hazard among coal miners. Inhalation of coal mine dust is known to cause several respiratory diseases. It has been recognized for decades that coal mine dust exposure can cause COPD.[9]

According to evidence from review of literature, the coal industry has been a powerful engine in Indian economic development, however, it also carries a high risk of occupational hazards. Out of several morbidities that can occur among them, it is evident that lung morbidity (specifically COPD) poses a serious threat to workers. An extensive literature search revealed only a few studies of comprehensive nature regarding coal industry. Among those studies, though many focused on pulmonary morbidities, different symptomatology of pulmonary problems was often taken as outcome measures and objective tests like pulmonary function tests were performed but other risk factors were not assessed. Thus, this study proclaimed to be unique in the ways of estimating the prevalence of COPD and its determinants among underground coal mine workers in Bankola Area, Durgapur, West Bengal.

METHODS

A cross-sectional study was conducted between June 2018 to August 2020 among the underground (UG) miners working in underground coal mines owned and operated by Eastern Coalfields Limited under Bankola Area. There was a total of 5732 workers registered. All the workers who were employees of E.C.L working underground (getting UG allowances) and directly involved in the process of coal production continuously for a period of minimum five year at time of study were included in the study after obtaining an informed written consent; while those who were absent on three consecutive days of interview were excluded. The ethical clearance was obtained from Institutional Ethics Committee.

Considering 95% confidence level and 7.5% absolute error, estimated sample size was calculated using Cochran's formula. Neelakanti et al found the prevalence of chronic respiratory morbidities to be 28.38% in a study conducted in South India.[10] Considering p=28.38, design effect=2 and non-response rate of 10% the final sample size was 315. From a total of seven underground mines under Bankola Area, three mines were selected by simple random sampling technique. The proportionate sample size was taken from each colliery by PPS method. Sampling frame was prepared separately from each mine. Sample was selected from the sampling frame by simple random sampling without replacement using random number table.

The study tools consisted of a pre-designed, pre-tested, semi-structured schedule on socio-demography and work-related environment, clinical COPD questionnaire (CCQ), stadiometer, portable analogue weighing machine, past medical records, stethoscope and spirometer (Table top Computer based spirometer RMS Helios-401, Computer based RMS Helios software, mouth piece and nose clip). The CCQ consisted of 10 questions distributed in three domains (symptom, functional state, and mental state) assessed by a seven-point scale from 0 to 6, which indicated the best (asymptomatic and no limitation) to the worst conditions (extremely symptomatic and limited), respectively. The CCQ total score was calculated by summing the scores of the 10 questions and dividing it by the number of items. A cut off score of 1.4 was considered for screening participants for spirometry evaluation.[11] The schedule was modified according to the local context and the objectives of the study. Face and content validity were checked by experts of Department of Epidemiology, All India Institute of Hygiene and Public Health, Kolkata. Pretesting of the schedule was done among a small representative sample in another

mine of the Eastern Coalfields and was rechecked by the experts, to ascertain reliability, objectivity, simplicity and to remove any ambiguity. All necessary corrections were made and the schedule was finalized.

Official permission to conduct the study was obtained from E.C.L. through proper channel. General Managers of respective areas were approached, who in turn directed the project managers of selected mines to kindly co-operate in the process of data collection. The list of workers, randomly selected for the study were displayed on the notice board at pit head offices. The workers were requested to kindly confirm their presence on one of the designated dates to their attendance clerk. Thus, a list of probable participants (25-30) was prepared and communicated to the researchers via the safety office every week. On every Friday, researchers visited the site and interviewed the participants at the project dispensary or the vocational training centre. Absent miners were telephonically requested to please attend the next session as per their convenience. After interviewing them with schedule, medical records were reviewed and the participants were enquired about the listed contraindications for spirometry. Then, it was followed by anthropometric measurements and spirometry. Initially, 146 participants were found eligible for spirometry on the basis of CCQ cut-off score. Among those, 3 participants had contraindications for spirometry. Thus, the spirometry was done on 143 miners. The spirometry findings were graded as per GOLD classification.[12]

Statistical analysis

Data were analysed using Microsoft Excel 2016 and Statistical Package for Social Sciences software (SPSS Inc., Chicago, IL, version 16.0 for Windows). Descriptive statistics were calculated and represented using various tables, graphs and diagrams. Inferential statistics had been performed to find out the predictors of the outcome. Bivariate followed by multi-variate analyses had been done. All tests were two tailed with p value <0.05 was considered significant throughout the analysis.

RESULTS

Regarding socio-demographic characteristics, most of the miners (41.2%) belonged to the age group of 45 to 54 years. The mean age was 48.4±9.0 years and it ranged from 28 to 63 years. Majority of the miners (91.7%) were Hindu, married (93%), belonged to nuclear family (63%). Almost half (48.8%) of the miners had 1 to 4 members in their family. The mean number of family members was 5.2±2.5 and it ranged from 2 members to 16 members per family. Majority (92.1%) of the miners belong to class I as per Modified B.G Prasad's Scale 2019. The mean per capita income was 14421.8±6961.3 INR and it ranged from 5000 INR to 50000 INR. Almost equal proportion of miners were educated till the level of higher secondary (23.8%) and graduation (23.5%), whereas only 8.3% of the miners were illiterate.

Table 1: Distribution of miners according to tobacco use pattern (n=139).

	Current smokers		Ex-smokers		Total
	Number	Percentage	Number	Percentage	Number (%)
Duration of smoking (in years)					
≤10	12	9.4	1	9.1	13 (9.3)
11-20	23	17.9	7	63.6	30 (21.5)
21-30	41	32.0	3	27.3	44 (31.6)
31-40	52	40.7	0	0	52 (37.6)
Total	128	100	11	100	139
Descriptive statistics (in years)	Mean±SD=24.6±9.5 Median (IQR)=28 (17-32) Range= (2,40)				

Table 2: Distribution of miners according to spirometry findings (n=143).

PFT findings	Number of miners	Percentage
Obstructive pattern	37	25.9
Restrictive pattern	15	10.5
Mixed pattern	33	23.1
Normal	58	40.5
Total	143	100
Severity* (n=37)		
Grade 1 (mild)	4	10.8
Grade 2 (moderate)	16	43.2
Grade 3 (severe)	14	37.8
Grade 4 (very severe)	3	8.2
Total	37	100

Continued.

Lung volume and capacities	Mean±SD value
FVC (% predicted)	82.26±22.7
FEV 1(% predicted)	78.09±29.5
FEV 1/FVC (% predicted)	87.65±26.3
*;Obstructive pattern	

Table 3: Association of COPD with sociodemographic, occupational and personal characteristics (n=315).

Variables		N	Number (%)	Chi square test X2, df P value
Sociodemographic characteristics				
Age (in years)	<50	138	18 (13)	0.399, 1 0.598
	≥50	177	19 (10.7)	
Level of education	Below middle	62	14 (22.6)	8.741, 1 0.005*
	Middle and above	253	23 (9)	
Substance use				
Ever smoker	Yes	139	26 (18.7)	11.622, 1 0.001*
	No	176	11 (6.3)	
Duration of smoking (in years)	≤20	219	17 (7.8)	11.000, 1 0.001*
	>20	96	20 (20.8)	
Frequency of smoking (units/ day)	≤5	225	21 (9.3)	4.422, 1 0.051
	>5	90	16 (17.8)	
Occupational/personal characteristics				
Years of work experience (in years)	<20	129	14 (10.9)	0.168, 1 0.725
	≥20	186	23 (12.4)	
Time spent at underground mine (in hours)	≤4	132	09 (6.8)	5.323, 1 0.022*
	>4	183	28 (15.3)	
Dust exposure area	High dusty area	115	25 (21.7)	17.448, 1 <0.001*
	Moderate dusty area	200	12 (6)	
BMI	≤22.9	74	09 (12.2)	9.569, 2 0.008*
	23-24.9	69	15 (21.7)	
	≥25	172	13 (7.6)	
Work at coal face	Yes	45	17 (37.8)	34.319, 1 <0.001*
	No	270	20 (7.4)	

*P-value is significant at <0.05, COPD was statistically significantly associated with education, ever smoking habit, duration of smoking, duration of underground mining, working in dusty area, BMI, working at coal face.

Table 4: Determinants of COPD (n=315).

Variables		OR (95% CI)	P valve	AOR (95% CI)	P valve
Age (in years)	<50	1	0.598	-	-
	≥50	1.10 (0.40-1.59)			
Level of education	Below middle	2.91 (1.40-6.07)	0.004#	2.06 (0.84-5.04)	0.111
	Middle and above	1		1	
Ever smoker	Yes	3.45 (1.63-7.26)	0.001#	2.26 (0.64-7.93)	0.202
	No	1		1	
Duration of smoking (in years)	≤20	1	0.001#	1	0.032#
	>20	3.12 (1.55-6.28)		2.91 (1.39-5.36)	
Frequency of smoking (units/ day)	≤5	1	0.038#	1	0.332
	>5	2.10 (1.04-4.24)		1.27 (0.16-1.85)	
Pack years*		1.14 (1.07-1.21)	<0.001#	1.03 (0.89-1.18)	0.682
Years of work experience (in years)	<20	1	0.682	-	-
	≥20	1.15 (0.57-2.34)			
Time spent at underground mine (in hours)	≤4	1	0.024#	1	0.810
	>4	2.46 (1.12-5.42)		1.12 (0.43-2.93)	

Continued.

Variables		OR (95% CI)	P valve	AOR (95% CI)	P valve
Dust exposure area	High dusty area	4.35 (2.09-9.05)	<0.001#	4.36 (1.83-10.41)	0.001#
	Moderate dusty area	1		1	
BMI	≤ 22.9	1	0.130	-	-
	23-24.9	2.00 (0.81-4.94)			
	≥ 25	0.59 (0.24-1.44)	0.250		
Work at coal face	Yes	7.58 (3.56-16.1)	<0.001#	8.55 (3.10-23.59)	<0.001#
	No	1		1	

#p-value is significant at <0.05 *Continuous variable; Hosmer and Lemeshow test (p =0.137), Nagelkerke R^2=0.322; Multivariate analysis revealed that miners who were smoking for more than 20 years, working in highly dusty areas and those who were working at coal face had higher odds of developing COPD.

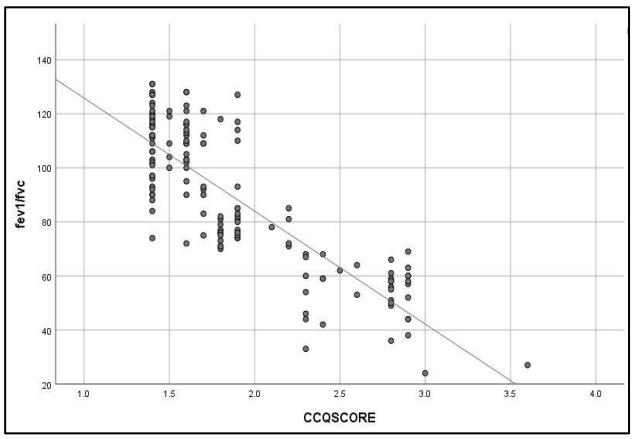

Figure 1: Scatter plot showing correlation between FEV1/FVC and CCQ score with a spearman coefficient: -0.802.

Regarding substance use, about 40% miners were using smoking tobacco whereas 45% were using smokeless tobacco and only 26% were alcohol users, whereas if current pattern of tobacco used was considered, about 33% miners were not using tobacco in form and among the users, most of them (27%) were using smokeless tobacco. Among current smokers, most of the miners (40.7%) had been smoking for more than 30 years whereas among ex-smokers 63.6% miners smoked for a duration of 11 to 20 years. The mean duration of smoking was 24.6±9.5 years and it ranged from 2 years to 40 years. Among both current smokers and ex-smokers, maximum frequency of smoking was 6 to 10 cigarettes per day. The mean number of cigarettes smoked per day was 6.6±2.7 whereas it ranged from 3 to 20 cigarettes per day. Regarding pack-years, the mean was 3.6±5.0 pack-years and it ranged from 0 to 38 pack-years. Almost similar percentage of miners (38% and 36.6%) were seen having a duration of use of smokeless tobacco from 21 to 30 years and 31 to 40 years respectively. The mean duration of use was 25.2±8.8 years and ranged from 6 to 40 years. Almost 56% miners used smokeless tobacco up to 5 times a day. The mean use was 5.3±1.2 times per day and it ranged from 3 to 10 times per day. Regarding alcohol use pattern, around 44% miners consumed alcohol for a duration of 21 to 30 years. The mean duration of use was 25.6±7.7 years whereas it ranged from 9 to 38 years. Around one third miners consumed alcohol for 1 to 2 times per week followed by 33.3% who consumed 3 to 4 times per week. Around three fourth of the miners consumed up to 480ml of alcohol per week. The mean quantity of alcohol consumed per week was 481.6±115.8 ml.

Table 5: Pulmonary function test (PFT) findings in ever and never smokers.

PFT findings	Ever smoker (n=81) Median (IQR)	Never smoker (n=62) Median (IQR)	Mann-Whitney U test P value
FEV1	79 (92-63.5)	83 (100-67)	0.166
FVC	62 (90.5-50.5)	89 (108-55)	0.002
FEV1/FVC	81 (103-60.5)	97 (115-74.5)	0.001

The table presents the median values and interquartile ranges (IQR) for Forced Expiratory Volume in 1 second (FEV1), Forced Vital Capacity (FVC), and the ratio of FEV1 to FVC (FEV1/FVC) among ever smokers (n=81) and never smokers (n=62). The p-values from the Mann-Whitney U test indicate statistically significant differences between the groups for FVC and FEV1/FVC, but not for FEV1.

Regarding occupational characteristics, majority (37.2%) had work experience of 23 to 28 years. The mean years of work experience was 20.49±8.08 years and it ranged from minimum 5 years and maximum 34 years. Most of the miners were working in mine development (23.2%) followed by engineers (18.7%) and least were working in support/stowing (4.2%). Majority of the miners were not working at coal face, only 14.3% were working at coal face. Around 40% miners were spending 6 hours per day at underground mine. The mean time spent underground was 4.39±1.84 hours.

Regarding personal health profile, almost 55% miners were obese whereas only 1.2% were underweight. The mean BMI was 25.64±3.46 kg/m^2. Pallor (44.7%) was the most common findings in general survey among the miners whereas around 20% had plantar fasciitis. Most of the miners (63.1%) did not report any type of pre-existing morbidity, whereas hypertension and diabetes were the two most common reported morbidity.

According to spirometry findings, the proportion of obstructive pattern among miners was 25.8% whereas 10.5% and 23.1% miners showed restrictive and mixed pattern respectively. Prevalence of COPD among miners was 11.7%. Most of the miners showing obstructive pattern, had Grade 2 severity of airflow limitation (43.2%) whereas 8.2% had Grade 4 severity.

Table 6: Pulmonary function test (PFT) findings based on miners working at the coal face (n=143).

PFT findings	Working at coal face Yes (n=26) Median (IQR)	Working at coal face No (n=117) Median (IQR)	Mann-Whitney U test p value
FEV1	73 (85.5-59.2)	83 (99.5-67)	0.034
FVC	54.5 (80.5-44)	83 (105-56)	0.001
FEV1/FVC	60.5 (92.2-56.7)	93 (112-74)	0.001

The table shows the median values and interquartile ranges (IQR) for Forced Expiratory Volume in 1 second (FEV1), Forced Vital Capacity (FVC), and the ratio of FEV1 to FVC (FEV1/FVC) among individuals working at the coal face (n=26) compared to those who do not (n=117). The Mann-Whitney U test reveals statistically significant differences in FEV1, FVC, and FEV1/FVC between the two groups.

COPD was statistically significantly associated with education, ever smoking habit, duration of smoking, duration of underground mining, working in dusty area, BMI, working at coal face.

Multivariate analysis revealed that miners who were smoking for more than 20 years, working in highly dusty areas and those who were working at coal face had higher odds of developing COPD.

In the present study, 10.5% miners showed restrictive pattern in their spirometry whereas 23.1% showed mixed pattern and 39.9% showed normal pattern. The mean % predicted FVC was 82.26±22.7, FEV1 was 78.09±29.5 and FEV1/FVC was 87.5±26.3. The Spearman's correlation coefficient between FEV1/FVC and CCQ score was -0.802 which depicted a strong negative correlation interpreting that, with decrease in FEV1/FVC, there was a significant increase in the CCQ score. In a sub-set analysis, it was found that the median FVC and FEV1/FVC among ever-smokers was significantly less compared to never smoker (p=0.002, p=0.001), similarly when compared with miners who worked at coal face and who did not work at coal face, the median difference of all the PFT parameters(FVC, FEV1, FEV1/FVC) were significantly less among who worked at coal face(p=0.034, p=0.001, p=0.001). Lastly, when it was compared with miners working in high dusty area and moderate dusty area, the median FEV1 and FVC were significantly low among miners working in high dusty area (p= 0.001, p=0.016).

DISCUSSION

The present study found 11.7% miners were diagnosed with COPD, among them 10.8% miners had grade 1 (mild obstruction), 43.2% miners had grade 2 (moderate obstruction), 37.8% miners had grade 3 (severe obstruction) and 8.2% miners had grade 4 (very severe obstruction) respectively based on GOLD classification. Among very few studies done on coal miners, González et al found the prevalence of COPD among coal miners to be 12.3%. Similarly Sood et al carried out a study to compare the prevalence of chronic obstructive pulmonary disease (COPD) between miners extracting coal versus other minerals and found that 16.9% miners had obstructive pattern in spirometry.[13,14] A study conducted among U.S coal miners by Reynolds et al found 11% miners depicting obstructive pattern in spirometry. Similarly in a study conducted on underground coal miners in Kentucky, Virginia and West Virginia by Blackley et al noticed that 6.7% and 4.6% of the miners from small and large mines respectively, showed obstructive pattern in their spirometry findings.[15,16] A cross-sectional survey among Ukrainian coal miners by Graber et al found that prevalence of chronic bronchitis to be 13.9%, while another cross-sectional study by Hendrynx et al found that prevalence of COPD was 27% which was far more than the present study. Similar study conducted by Reynolds et al on Welsh slate miners, where he included miners and non-miners found that COPD was significantly more common in miners (33%) which is almost double compared to the present study and among non-miners the prevalence was 26%.[17-19] The only study done among coal-miners of Brajarajnagar under Mahanadi Coalfields Limited (MCL) have reported much less prevalence of obstructive disorder (1.8%). Another study conducted among Indian coal miners in the southern part of India reported 28.3% miners suffering from chronic respiratory morbidities which is much more compared to the present study.[20,21] According to the Global Burden of Disease Study 1990-2016, the prevalence of COPD in general population in India was 4.2% in 2016 as compared to 3.3% back in 1990.[22] So, it is evident from the present study findings that coal miners are at more risk of developing COPD compared to general population.

In the present study, miners working in high dusty area (AOR- 4.36, p=0.001) and working at coal face (AOR-8.55, p<0.001) were significantly associated with COPD. Smokers who smoked for more than 20 years showed a significant association with COPD (AOR- 2.91, p=0.032) whereas ever smoker and pack years were found to be non-significant. Similar association was seen in a cross-sectional study conducted in the southern part of India to find out the relationships of individual and work-related factors with obstructive type lung function disorder of underground coal miners reported significant association between COPD and work at coal face, present age, smoking habit and underground exposure years. BMI was statistically non-significant.[23] Another cross-sectional survey among Ukrainian coal miners by Graber et al found that working at coal face is one of the risk factors associated with chronic bronchitis, OR-1.12 (1.03-1.21).[17] A cohort study conducted to determine the mortality of Dutch coal miners in relation to pneumoconiosis, chronic obstructive pulmonary disease, and lung function reported mortality due to COPD was significantly associated with duration of exposure and persons who were smokers. The study also found that miners with BMI<20 resulted in a significant increased SMR for COPD.[24] Another cohort study conducted to find out the rapid declines in FEV1 and Subsequent Respiratory Symptoms, Illnesses, and Mortality in Coal Miners in the United States found statistically significant association of age and current smokers with COPD.[25]

The current study found that obstruction was the most common abnormal spirometry pattern noted among all miners as found in a study by Sood et al.[14] A cross sectional study conducted in the field area of MCL near Brajarajnagar also found 20% of workers having abnormal spirometry finding suggestive of obstructive, restrictive and mixed type of respiratory problem, though restrictive type was maximum (17.3%).[20]

The current study had faced some limitations. The results of this study could only be generalised to the underground miners of coal mines owned by Eastern Coalfields Limited. These findings could not be generalised to all miners of ECL or miners in other parts of the country. The study being carried out at the workplace had the limitation that some study subjects might have inadvertently masked the true facts along with dust exposure evaluation and quantification could not be done in the present study.

CONCLUSION

Coal mines being a dust intensive industry invariably poses a high risk for development of COPD. The coal miners who worked in areas where dust concentration was more and they had to work in close vicinity to coal extraction site showed increase risk of developing COPD. Smoking being the first and the foremost cause of developing COPD was found evident among miners who smoked for significant period of time. Thus, the high prevalence of smoking tobacco use among coal miners further increases the risk of having COPD among them. Addressing substance use as well as improvement in working environment including use of personal protective equipment can holistically lead to better respiratory health of the miners.

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